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KATHLEEN FREEAR, WILFRED BUCKLEY

AND

R. STENHOUSE WILLIAMS

RESEARCH INSTITUTE IN DAIRYING,
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TO

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Lecturer on Agriculture and Manager of the College Farm,
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A STUDY OF TWO TYPES OF COMMERCIAL MILK[1].

THE work contained in the following pages originated from two events. First, that in the autumn of 1916 the Board of Agriculture and Fisheries granted permission to members of the Staff of the Research Institute in Dairying to undertake the bacteriological examination of samples of clean milk which was being produced for commercial purposes, and second, that in November, 1916, the Committee of the Research Institute in Dairying appointed a Sub-Committee to "formulate and present to the Committee proposals for the development of the work of the Research Institute in Dairying."

The Sub-Committee was of opinion that the members of the Staff of the Research Institute could organize their work to the greatest benefit of the milk and dairy world if they possessed statistics, which did not exist at that time, of the losses and causes of loss in these industries. An enquiry was therefore set up which revealed among other facts that the milk which is supplied to our great towns is subject to a loss of from 1 to 2 per cent. due to "souring," and that of the remainder a very considerable proportion arrives in such a condition that it is necessary to pasteurize it before it can be delivered to the consumer. Since about 70 per cent. of milk is consumed as milk, these losses represent a grave wastage of food stuff, money and labour. Estimates of the extent of these losses and suggestions of methods for their improvement were published in *The Milk Supply—A Suggestion* (1) and in the *Journal of the Royal Agricultural Society of England* for 1918 (2), and evidence was given before the Interdepartmental Committee on Milk Production. Some of the recommendations which were made in the papers and in the evidence which was given before the Committee were adopted in the *Second Interim Report* of the Committee which was published in December, 1917 (3). The members of the Staff of the Research Institute, however, realized that although the recommendations which they had made tended to diminish loss of food stuff and of money, they only improved the quality of the milk to a limited extent. They therefore set themselves to find out what steps could be taken to improve the general level of market milk in the country. As a first step it was decided that a study of the relative keeping qualities of clean and average milk produced for commercial purposes should be added to the study of their bacteriological content. This work began on May 31st, 1917, and the records of the results, to May 30th, 1918, combined with those of the study of the bacteriological content of the two types of milk since November, 1916, are here given. They reveal the fact that whereas the clean milk, which had travelled from 22 to 26 hours before its arrival and had been subjected to the varying conditions of temperature which such a journey involved, remained sweet for a period which was never less than 1·75 days even at room temperature, the average milk, which was only three hours old when the study of its keeping qualities was begun, failed to remain sweet for 24 hours at room temperature on thirteen occasions in the course of the year. Similar results were obtained when the samples were kept in a cellar which maintained a lower temperature than the room, and in the ice chest, the temperature of which approximated to freezing point. The bacteriological results show that the bacterial content of the clean milk only rose above 10,000 upon two occasions, once on June 14th, 1917, when the count was 200,000 in 1 c.c. of the milk, but no lactose fermenting organisms were found in 1 c.c. of this sample; and again on October 18th, 1917, a sample was examined, the numbers of bacteria in which could not be counted in $\frac{1}{10,000}$ c.c. and lactose fermenting organisms were found in $\frac{1}{100}$ c.c. This is the only occasion upon which what may be described as a truly unsatisfactory result has been obtained from the bacteriological examinations of the samples of clean milk from November, 1916, to May 30th, 1918. Since the series which is here described was closed, the examinations have been continued week by week and the results obtained for the period June to November, 1918, confirm those which are presented in this account.

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[1] A grant from Messrs Nestlé and Anglo-Swiss Condensed Milk Co. has made it possible to print this work.

The bacteriological examinations of the average milk show an entirely different picture, in spite of the fact that its age at the time of examination (4 to 12 hours as compared with 22 to 26 hours) was very much less than that of the clean milk; for while the bacterial count of the clean milk maintains an almost uniform level, that of the average milk varies greatly from week to week, so that on one occasion it may be below ten thousand and on another fourteen millions or more. It is further found that whereas in clean cooled milk, organisms capable of producing acid and gas in lactose peptone water were present upon only eight occasions, and that the smallest quantity of milk in which they were obtained was $\frac{1}{100}$ c.c., in the average milk they were found on forty-nine occasions, and the smallest quantity of milk in which they were present was $\frac{1}{10,000}$ c.c. There was therefore a great difference both in the keeping qualities and in the bacterial content between these two sets of samples of milk, and this difference is not explained by the fact that the clean milk was cooled at the farm, whereas the average milk was only cooled during a period of about six weeks from November to January in each year. If the records of the samples of cooled average milk be examined the same irregularity in the bacterial counts and in the evidence of the presence of lactose fermenting organisms is found as occurred during the months when the milk was not cooled. The real explanation of the difference lies in the care which was taken to exclude extraneous matter from the clean milk, and the absence of such care in the production of the average milk.

An account of the methods which were adopted in the two cases is included in this work. It shows that the average milk was produced under conditions which left much to chance. There was no consistent attempt to secure that the cows, the milkers, or their utensils were clean at the time of milking. On the other hand, in the production of the clean milk every effort was made to secure the cleanliness of the cows, the milkers and all the utensils. The result appears to be worthy of the labour involved, especially when it is remembered that the cost of the clean milk when delivered in churns is not more than 3*d.* a gallon above the market price.

A study of that section of this work which deals with the methods adopted in the production of the clean milk shows that a very considerable outlay of capital was involved. It has been thought well therefore to set up a series of experiments to study the influence of each detail of the work upon the final product and to demonstrate how a dairy farmer may most readily and economically pass from the production of average milk to the production of clean milk.

It may be of interest to point out here that the production of clean milk depends upon three things, an adequate financial return for the extra labour involved, a sufficient supply of the proper apparatus, and workers who possess not only intelligence and enthusiasm but also that kind of vision which is not dependent upon the eye alone for its conception of "dirt." The importance of this factor was brought home to us when we began this work in November, 1916. Three dairy farmers expressed the wish that their milk should be examined. On one of these farms no proper provision had been made for the production of clean milk and the samples soon ceased to come. On the second considerable sums of money had been expended in providing a milking shed of the most approved type and all the apparatus necessary for the production of clean milk, yet the samples which were sent to the laboratory for examination were rarely up to standard, and when visits were paid to the farm at milking time grave errors in the methods of production could always be demonstrated. Eventually the samples of milk ceased to be sent to the laboratory. It is true that the owners of this farm started this work under conditions made difficult by the war, but it is equally true that at no time was the work under the control of a person with the right kind of vision and sufficient enthusiasm to inspire those who were responsible for the carrying out of the details. If clean milk production is to become at all general in this country it will be necessary that a greater number of persons than exist at the present time shall be trained in the technical details of the work. With this object in view two steps have been taken, the dairy teachers have been gathered together to consider what measures can be adopted to promote the teaching of the best methods of milk production in our dairy schools, and an appeal has been made that only those who have given evidence that they have a satisfactory knowledge of their work shall be permitted to undertake the production of milk (2).

Methods of Production and Distribution of the Clean Milk.

The cows were milked in a special milking barn which was kept scrupulously clean. After each milking the floor, gutters, walls and mangers were washed and cleansed thoroughly, and in the morning the walls, which were finished with smooth cement, were scrubbed with a brush.

The cows were brought into their standings night and morning and were so arranged that they faced inwards. By this arrangement the light from the windows or from the electric light on the walls fell upon their hind quarters, and the workers were able to see exactly what they were doing. At each milking the cows were carefully cleaned and groomed. All visible dirt was removed from their hind quarters by means of water, brushes and curry combs. The udders and teats were washed with cold water and afterwards wiped with a clean damp rag. The hair on the udder was always kept short by means of a horse clipper, and the brush of the tail was cut so that it might not reach beyond the hock. The milkers kept their nails short and always carefully washed their hands immediately before milking each squad of cows or more frequently if necessary. The men wore white caps and overalls, the lower half of the latter being split up the middle so that each half might be tied behind the leg which by this means was entirely covered. The women wore smocks over their dresses. The overalls and smocks were worn only while the cows were being milked, and were taken off while they were being groomed. The milking stools were always kept very clean that the hands of the milkers might not be made dirty. Milking was done by hand into buckets of such a shape as to prevent as much as possible falling hair and dust from getting into the milk. The buckets were entirely covered, the only opening being a hole $4\frac{3}{4}$ in. in diameter at the top of the side, and placed at such an angle that every point of the interior could be clearly seen. At the top of the opening was a little guard to prevent any foreign material which might have fallen on the bucket from getting into the milk as it was poured out. When milking the milkers rested their heads as little as possible against the cows' flanks so that dust or loose hair might not be disturbed. The milking was carried out with dry hands, and the first two squirts of milk from each teat were allowed to fall on the concrete floor. The milk from each cow was immediately removed to the weighing room which adjoined the milking barn. It was then carried along a path to the Dairy which was situated at a distance of 20 yards from the milking barn. The milker did not enter the Dairy but poured the milk into a small receiving tank which was placed on a bracket outside the wall of the Dairy immediately before each milking. The tank had a removable tube at the bottom which passed through a hole in the wall of the Dairy and conducted the milk to a Ulax filter which was set over a tank inside the Dairy from which the milk flowed over a cooler. The water for the cooler was obtained from a deep well. This water had been analysed and had been described as "of unusual purity." The milk fell from the cooler into a churn if it was to be delivered in churns, but if it was to be sent away in bottles it went into a bottle-filling machine when there was a large number of bottles to be filled, or directly into the bottle if there was a comparatively small number.

When the milk was in the bottle a sterilized disk was put in the neck by means of a small automatic hand machine, and a paper cap was then placed over the top of the bottle and fastened around the neck with wire that was crimped by a second small hand machine. This cap protected from contamination the lip of the bottle, which, were it not covered, would be handled frequently before the milk was poured over it; it also prevented dust, etc., from lodging on the disk and falling into the milk when the bottle was opened. The bottles of milk were then packed in boxes and were ready for transit.

The milking buckets were first rinsed with cold water, then scoured well with Sunlight and monkey soap in hot water to which lux had been added, then placed in a tank of cold water and finally rinsed with a jet of cold water from a hose pipe and placed in a sterilizing tank into which steam was turned for twenty minutes and in which they remained until needed for the next milking. The receiving tank, the strainer and the cooler were all carefully washed and treated with current steam in the same way as the buckets.

The bottles were washed in a bottle-washing machine. First they passed through a bath of a solution of caustic alkali which was kept in motion, then they fell into a rinsing tank and afterwards they were put by hand over a revolving brush and their outer surfaces were cleansed at the same time by another revolving brush. They were then inverted over a jet of clean water which rinsed them and finally put in crates and treated with steam in the way that has been described.

The Dairy contained a room for the boiler and sinks, and a tank in which the bottles and utensils were steamed before use. In a second room the milk was cooled and bottled or run into churns. This room also contained the bottle washing machine, but after the war this will be removed to another room built for the purpose. It is also proposed to install a refrigerating plant so that the milk can be cooled immediately to a constant temperature.

The Method of Production and Distribution of the Average Milk.

The cows were milked in the byre at all seasons of the year. During the summer from May to November they were out in the fields day and night and were brought up to the cow shed to be milked. After the morning milking the floors and gutters were washed and after the afternoon milking they were brushed up. During the winter the cows were sleeping in the byre, they were bedded down with straw and the morning milking was carried out before the cow shed was cleaned. After the morning milking the cows were turned out, the shed was cleaned, the floor and gutters were washed, the soiled bedding was removed and fresh straw was added ready for the cows when they came in in the afternoon.

In the summer, the cows were brushed once a day before the morning milking, but beyond a superficial wipe of the teats with a cloth which had been dipped in a bucket of water no further attempts were made to secure their cleanliness at the time of milking. In the winter the brushing and washing of the cows was carried out after the morning milking and brushing in the afternoon before milking. The only light available for the morning milking in the winter time was that which was given by a portable oil lamp.

The cleanliness of the hands and of the clothes of the milkers was uncertain, some of them wore overalls, others did not, and none of them washed their hands after they had tied up the cows and before they began to milk. The milking was done by hand into open pails. The milk from each cow was carried to the weighing machine which was fixed on the wall of the cow shed with a tared bucket attached. The wall was situated at a distance of six feet from the cows. The milk from each cow was poured into the bucket and weighed, and when it was full its contents were poured into another bucket which was often allowed to remain on the floor of the cow shed until there were two full buckets ready for removal to the dairy where it was poured through a flannelette strainer and without being cooled was passed into a churn. For a period of about six weeks during January, November and December of each year the milk was strained and then passed over a cooler, the water for which was obtained from the town supply. The strainers were not boiled, but were cleansed with the other utensils in the manner which is described below.

After the morning milking the utensils used at the farm were first rinsed with running water obtained from the town supply, they were then placed in a tank made of galvanized zinc containing from 8 to 10 gallons of water at such a temperature that the workers could comfortably bear their hands in it. To this water an unmeasured quantity of soda was added. With the aid of a cloth all the utensils which included from three to six buckets, strainers, measures, etc., were cleansed in this solution which remained unchanged throughout the process. The utensils were not rinsed in clean water after they had been washed in the soda solution, but were immediately placed upside down in the dairy and left to dry. After the afternoon milking the utensils were washed with cold water only; they were then inverted and left to dry ready for the morning milking.

When the milk cans reached their destination they were first emptied, then washed with cold water and finally inverted over a steam jet for a period which did not exceed 10 seconds on those occasions when a record of the time was taken. The milk cans were then returned to the farm.

Variations in the temperatures of cooling and temperatures on arrival at the Laboratory of the Clean Milk.

It has already been stated that the milk was cooled with water from a deep well and Table I, which has been prepared from Appendix I, demonstrates that during the period of the observations this method did not give constant results since the extent of cooling of the milk varied as much as 17° F., the highest record obtained being 62° F. and the lowest 45° F. It is clear that at the time of milking the milk was only occasionally cooled to a low temperature and the need for the refrigerating plant which it is proposed to install is made evident.

After cooling and bottling pint bottles of this milk were taken without any special selection from among those which were being sent out from the afternoon milking. This began at about 2 p.m., and the milk was sent off about 4 p.m. It then travelled by rail and reached the laboratory at about 1 p.m. to 2 p.m. of the following day. The milk was therefore about 22 to 24 hours old at the time of its arrival at the laboratory. Beyond the fact that it travelled in a ventilated box no attempt was made to maintain a low temperature during the journey. Indeed the milk was sometimes subject to disadvantages since it was sent in pint bottles and therefore assumed the temperature of the surrounding atmosphere more readily than it would have done if it had been transmitted with corresponding care but in greater bulk. Table I shows the temperatures to which the milk was originally cooled and

Table I. *Clean Milk.*

Date	Temp. after cooling	Temp. on arrival	Date	Temp. after cooling	Temp. on arrival
16– 8–17	59·5° F.	65° F.	17– 1–18	45° F.	44° F.
23– 8–17	62	69	24– 1–18	50	56
30– 8–17	56	61	31– 1–18	Not taken	45
6– 9–17	62	68	7– 2–18	50	55
13– 9–17	58	60	14– 2–18	50	48
20– 9–17	58	63	21– 2–18	Not taken	46
27– 9–17	56	61	28– 2–18	48	49
4–10–17	56	60	7– 3–18	49	46
11–10–17	56	52	14– 3–18	50	51
18–10–17	56	54	21– 3–18	51	52
25–10–17	52	54	28– 3–18	50	50
1–11–17	55	58	4– 4–18	50	51
15–11–17	52	51	11– 4–18	54	50
22–11–17	52	57	18– 4–18	50	44
29–11–17	51	62	25– 4–18	51	55
6–12–17	50	43	2– 5–18	52	50
13–12–17	50	50	9– 5–18	55	56
20–12–17	46	37	16– 5–18	54	63
27–12–17	Not taken	49	23– 5–18	62	60
3– 1–18	46	50	30– 5–18	57	66
10– 1–18	51	49			

those at which it arrived at the laboratory, and demonstrates that although there were occasions when the temperature of the milk was lower at the time of its arrival at the laboratory than it was when cooled, yet there were other occasions when the temperature of the milk on arrival at the laboratory was very distinctly higher than it had been at the time of cooling. In one case this difference between the temperature of cooling and the temperature on arrival was as much as 11 degrees.

Division of the Samples.

Average Milk.

Milking began at about 6 o'clock in the morning and the churns of milk reached the dairy about half past eight. The samples were taken at nine o'clock. The procedure was as follows: a churn was opened and the temperature of the milk was taken. The milk in the churn was then thoroughly mixed by means of a plunger which had been carefully washed and steamed in current steam. By means of a ladle three portions of between 6 and 7 oz. each were poured through a glass funnel into glass bottles which were then plugged with cotton wool. All the necessary apparatus had been carefully sterilized before use. One of these bottles was placed in the ice chest, a second in the cellar and the third in the laboratory in order that a daily test of their keeping qualities under these varying conditions might be carried out. The samples which were kept in the laboratory were subject to marked fluctuations of temperature, those in the cellar to fluctuations which were of a less violent character, and those in the ice chest to temperatures which varied from 31° F. to 38° F.

It will be noticed that the tests for the keeping qualities of these samples of milk began when the milk was about three hours old. The tests of the bacterial content were made in the afternoon when the clean milk arrived and were taken from the sample which had been kept in the laboratory.

The duration of sweetness of the samples was tested in the following way: the cotton wool plugs were removed from each bottle in the laboratory once daily and a sample of milk from it was poured out into a clean beaker. The cotton wool plugs were then replaced in their respective bottles but no attempt was made to keep either the plugs or the mouths of the bottles sterile. The sweetness or otherwise of the sample was tested by taste and smell. When the sample in the laboratory ceased to be sweet, then the examination of the corresponding sample in the cellar was begun, and when that ceased to be sweet, a daily examination of the corresponding sample in the ice chest was made.

Clean Milk.

The bottles of milk were thoroughly shaken, Their outside caps and inside disks were removed by means of a sterile instrument. The temperature of the milk was then taken, and a sample was removed for bacteriological examination. The remainder of the milk was divided into three portions by pouring it through sterile funnels into sterile glass bottles which were then plugged with sterile wool. These three portions were placed in the ice chest, the cellar and the laboratory, and their periods of sweetness were tested in the manner which has been already described.

Periods of Sweetness of Clean Milk when stored at different Temperatures.

The keeping qualities of these samples of milk were of so uniform a character and depended so much upon the temperatures to which they were cooled, the temperatures at which they travelled and the temperatures at which they were subsequently kept in the laboratory that it seems advisable to consider the one case in which the technique was probably at fault before discussing the general results of the experiments. This sample of milk reached the laboratory on May 2nd, 1918. It had been cooled to a temperature of 52° F. and arrived at a temperature of 50° F. It was $22\frac{1}{4}$ hours old when it reached the laboratory. Its bacterial count was 400 in 1 c.c. and no lactose fermenting organisms were found in the same quantity. There was therefore no evidence of unsatisfactory treatment either in the methods of its production or in the extent of cooling or in the duration of the journey before it arrived. None the less its periods of sweetness when samples were placed in the ice chest, the cellar and the laboratory were in all three cases 1·75 days. The experiments do not show whether the failure in the keeping qualities of this sample was due to an error in technique at the farm or in the distribution of the samples in the laboratory or some other cause. It may be said that this is the only sample which has behaved in this way since the experiments on the keeping qualities of the milk were begun on May 31st, 1917. This monograph contains the account of fifty-one of these samples from May 31st, 1917, to May 30th, 1918, but since the latter date the work has been continued and between June 6th, 1918, and the 28th November, 1918, a further series of 26 samples has been tested. There has been no recurrence of such an incident as happened on May 2nd, 1918. The final result therefore is that 77 samples have been examined between May 31st, 1917, and November 28th, 1918, and the keeping qualities of one of these were under the conditions of the experiments not so good as to correspond to the high level which the remainder had set. The effect of this sample upon the uniformity of the curves illustrating the keeping qualities of this milk is well shown in Chart I.

During the year May, 1917, to May, 1918, 51 samples of milk were received. The duration of sweetness of all these was tested in the cellar and in the laboratory, but for a period of six weeks from March 7th to April 11th, 1918, no samples were put in the ice chest. This fact reduces to 45 the number of samples which were studied in the ice chest.

A consideration of the figures in Table II shows that this milk although it was already 22–26 hours old when it reached the laboratory, and although its temperature on arrival varied from 76° F. to 37° F. yet remained sweet in the ice chest for periods of time which, with the exception of the instance to which reference has been made, varied from 7·75 days to 32·75 days; in the cellar from 1·75 days to 18·75 days, and in the laboratory from 1·75 days to 6·75 days. It further appears that in spite of the unsatisfactory conditions of temperature during transit to which this milk was sometimes subject, and of the length of time of its journey, on no occasion did it arrive sour, and its subsequent period of sweetness under the very varying conditions of temperature which were found in the laboratory, was not less than 18 hours, that is to say, it remained sweet for a period which was never less than 1·75 days from the time of milking.

Table II. *Sweetness of Milk in Days.*

Days	Storage		
	Ice chest	Cellar	Laboratory
32·75	1	—	—
31·75	—	—	—
30·75	—	—	—
29·75	—	—	—
28·75	1	—	—
27·75	1	—	—
26·75	1	—	—
25·75	—	—	—
24·75	2	—	—
23·75	—	—	—
22·75	3	—	—
21·75	—	—	—
20·75	—	—	—
19·75	4	—	—
18·75	1	1	—
17·75	4	—	—
16·75	—	—	—
15·75	4	—	—
14·75	4	1	—
13·75	6	—	—
12·75	3	1	—
11·75	3	3	—
10·75	3	—	—
9·75	—	2	—
8·75	1	2	—
7·75	2	9	—
6·75	—	3	5
5·75	—	5	6
4·75	—	4	7
3·75	—	8	10
2·75	—	8	12
1·75	1	4	11
Less than 1·75	—	—	—
Total number of samples	45	51	51

Seasonal variations in the keeping qualities of Clean Milk.

The term "seasonal variations" includes all those factors such as the cleanliness of the cow, the methods of milking and the variations in temperature, etc., which when taken together tend to hasten or delay the souring of the milk. Since atmospheric changes are included among these factors the importance of "seasonal variations" is most readily estimated in this series of experiments by the study of those samples which were kept in the cellar and in the laboratory.

Table III shows that of seventeen samples which were kept in the laboratory between May 31st and September 27th, 1917, eight were sweet at the end of 1·75 days, eight at the end of 2·75 days, and one at the end of 3·75 days; whereas of 29 samples which arrived between October 4th, 1917, and April 25th, 1918, one was sweet at the end of 1·75 days, two at the end of

Table III. *Period of Sweetness.*

PERIOD	NO. OF DAYS sweet	LABORATORY No. of samples	CELLAR No. of samples
31-5-17—27-9-17	1·75	8	2
	2·75	8	8
	3·75	1	5
	4·75	—	2
		Total 17	Total 17
4-10-17—25-4-18	1·75	1	—
	2·75	2	—
	3·75	8	1
	4·75	7	2
	5·75	6	4
	6·75	5	3
	7·75	—	9
	8·75	—	2
	9·75	—	2
	10·75	—	—
	11·75	—	3
	12·75	—	1
	13·75	—	—
	14·75	—	1
	15·75	—	—
	16·75	—	—
	17·75	—	—
	18·75	—	1
		Total 29	Total 29
2-5-18—30-5-18	1·75	3	2
	2·75	2	—
	3·75	—	2
	4·75	—	—
	5·75	—	1
		Total 5	Total 5

2·75 days, eight at the end of 3·75 days, seven at the end of 4·75 days, six at the end of 5·75 days and five at the end of 6·75 days.

In the same way it is found that of the seventeen samples which arrived between May 31st and September 27th, 1917, and were then kept in the cellar, two remained sweet for 1·75 days, eight for 2·75 days, five for 3·75 days and two for 4·75 days, whereas the shortest period of sweetness shown by those samples which arrived after that date was 3·75 days upon one occasion, all the remaining twenty-eight samples keeping sweet for periods of 4·75 days or longer.

The five samples which arrived during May, 1918, showed a return to the conditions found at the same period of the year 1917. In the laboratory three remained sweet for 1·75 days and two for 2·75 days; in the cellar two remained sweet for 1·75, two for 3·75 and one for 5·75 days.

The seasonal variation is further brought out by the curves shown in Chart I which gives in chronological order the periods of time during which the samples of milk remained sweet in the ice chest, the cellar and the laboratory. It also gives the temperatures of the milk on arrival and the averages of the maximum and minimum temperatures to which the samples were subjected after arrival. A general survey of these curves shows that there was a seasonal curve: thus the duration of sweetness of the samples of milk which were kept in the cellar and laboratory during the periods from May 31st to September 27th, 1917, and during May, 1918, was clearly shorter than at any other period under review.

The samples which were tested during the months of October and November, 1917, remained sweet for more prolonged periods than those which had been tested during the previous months, and this improvement in the keeping qualities of the samples became even more pronounced during the months of December, 1917, and January, February and March, 1918. In April, 1918, the period of sweetness of the samples declined to a level similar to that found in October, 1917, and in May, 1918, they approximated to those found during the period May to September, 1917. It was thought that since the samples of milk which were kept in the ice chest had travelled for periods of 22 to 26 hours before they were stored at a temperature which only varied a few degrees throughout the experiments, they might show variations in their keeping qualities which would correspond to some extent with those which were found in the cases of the samples which were kept in the cellar and in the laboratory. The curve of the duration of sweetness of the samples which were stored in the ice chest which is shown in Chart I was therefore prepared, and it presents features which in many respects closely resemble those obtained for the samples which were stored in the cellar and in the laboratory. Thus, the curve of the duration of sweetness of the samples is lowest during the months of May and June, improves during July, August, September and the earlier part of October when it declines once more until it reaches the minimum point of this wave at the end of November. This wave is followed by a rise of which the maximum point is reached when the lowest temperature of the milk on arrival at the laboratory is attained. This again is followed by a period of fall which is associated with an increase of the temperature of the milk on arrival, but never reaches a point so low as that which was found either in June or in November, 1917. No samples were placed in the ice chest during the period from March 7th to April 18th, 1918. When this portion of the work was resumed on April 18th, the duration of sweetness of the samples, with the exception of that one which has already been discussed, had returned to the level found in May and June, 1917. The curve indeed very closely resembles that of the samples which were preserved in the cellar.

Influence of the "Temperature on Delivery" and of the "Temperature after Delivery" upon the duration of sweetness of the samples of Milk.

If the curve for the ice chest in Chart I be examined, it is seen that the period of sweetness of those samples which arrived at a higher temperature was on the whole shorter than that of those which arrived at a lower temperature. If the curves for the ice chest, cellar and laboratory be examined it is found that the period of sweetness of the portions of any one sample which were kept in the laboratory was shorter than that of those which were kept in the cellar, and this again was shorter than that of those which were kept in the ice chest. Now the average temperatures in the laboratory were higher than those in the cellar, and those in the cellar were higher than those in the ice chest. These facts seem to indicate that the temperature of the milk on arrival at the laboratory and the temperatures at which the samples were subsequently kept, had an influence upon the length of time during which the milk remained sweet. It may be well therefore to study the influence of the "Temperature on Delivery" and of the "Temperature after Delivery" upon the keeping properties of the samples under consideration. In the term "Temperature on Delivery" are included all those factors which had led up to the condition of the milk as it arrived in the laboratory. These factors included cleanliness, which the bacteriological report shows must have been remarkably constant; initial cooling, variations of temperature during the journey and the duration of the journey. The duration of the journey was almost constant 22–26 hours. There remain the initial cooling and the temperatures encountered during the journey. The records of the temperatures to which the milk was cooled and the temperatures at which the samples arrived at the laboratory show that these varied in the same sense. The cooling was therefore least efficient when the temperature conditions during the journey were most likely to have an unfavourable influence upon the keeping qualities of the milk.

The great influence of the "Temperature on Delivery" and of the "Temperature after Delivery" upon the duration of sweetness of the milk is demonstrated in Table IV in which the average periods of sweetness of the samples which were kept in the ice chest, the cellar and the laboratory have been tabulated in reference to the temperatures at which they arrived, and in reference to the temperatures at which they were subsequently kept by grouping together all those samples which arrived at temperatures from 61° to 70° F., 51° to 60° F., and 41° to 50° F., and by including in the table the maximum and minumum temperatures with the averages of these for each group. For purposes of comparison the samples which arrived at the two extremes of temperature (76° F. and 37° F.) have been included. Two samples arrived at 71° F. The results obtained with them are shown in the table but it is felt that the number is so small that it does not form a fair comparison with the other groups.

Influence of the "Temperature on Delivery."

The influence of "temperature on delivery" is most clearly brought out by the periods of time during which those samples which were kept in the ice chest remained sweet, since the temperature of the ice chest did not vary more than 9° F. throughout the whole course of the experiments. Table IV shows that the sample of which the "temperature on delivery" was the lowest (37° F.) had the longest period of sweetness (32·75 days) in the ice chest, whereas the duration of sweetness of that sample which arrived at 76° F. was only 7·75 days. The one sample which remained sweet for 1·75 days has been already discussed.

Corresponding results are found if a study be made of the average periods of sweetness of those samples which arrived at temperatures between these two extremes. Thus those samples which arrived at temperatures between 41° F. and 50° F. remained sweet for an average period of 17·5 days, those which arrived at temperatures between 51° F. and 60° F. for an average period of 16·8 days and those which arrived at temperatures between 61° F. and 70° F. for an average period of 14·0 days.

From these figures it appears that the "temperature on delivery" had an important influence upon the duration of sweetness of the milk after delivery.

This fact is well brought out in Chart II which shows the length of time during which the samples received between May, 1917, and February, 1918, remained sweet in the ice chest. The maximum and minimum temperatures to which the samples were cooled and the variations of temperature in the ice chest during the period of the experiments are given. The samples are set out in the Chart according to the temperatures in ° F. at which they reached the laboratory and the number of days that each sample remained sweet in the ice chest is indicated. When the points indicating these days are joined together a curve is obtained which is at its maximum height when the

Table IV. *Influence of Temperature.*

		ICE CHEST					CELLAR					LABORATORY				
Temp. on delivery	No. of samples	Aver. period of sweetness in days	Min. temperature	Max. temperature	Aver. min. temp.	Aver. max. temp.	Aver. period of sweetness in days	Min. temperature	Max. temperature	Aver. min. temp.	Aver. max. temp.	Aver. period of sweetness in days	Min. temperature	Max. temperature	Aver. min. temp.	Aver. max. temp.
76° F.	1	7·75	34	37	34·1	36·7	2·75	61	64·5	61	64·2	1·75	69·5	72	69·5	72
71	2	15·25	33	37	34·2	36·1	3·75	58	65	60·0	61·1	2·75	63	74·5	64·7	73·2
61–70	15	14	32	40	33·7	36	3·35	44	66	57·7	59·5	2·28	53	76	59·8	67·6
51–60	17	16·8 (14 sam	32 ples)	40	33·4	35·6	5·8	43	61	49·27	51·47	3·92	41·5	72·5	51·8	62·6
41–50	15	17·5 (12 sam	31 ples)	35·5	33	34·7	9·28	35	49	42·4	44·18	4·95	35	73·5	44·7	56·9
37	1	32·75	31	35·5	32·7	34·4	18·75	38	41·5	39·2	40·1	6·75	37·5	70·5	39·9	58·5

sample was cooled to 45° F. and reached the laboratory at 37° F. and at its minimum height when the milk was cooled to 62° F. and reached the laboratory at 76° F. The periods of sweetness of the samples which were cooled and travelled at temperatures between these lie at points between these extremes.

In view of the facts that the temperature of the ice chest did not vary more than 7° F. throughout the experiments and that the bacterial counts of the samples were remarkably uniform it appears to be clear that the curve which has been obtained was chiefly due to the temperatures of cooling and the temperatures encountered during the transit of the milk. The importance of uniformity of temperature of cooling and of temperature during transit are thus made evident.

Influence of the "Temperature after Delivery."

If the figures given in Table IV be examined it is found that the duration of sweetness of those samples which arrived at any given temperature is always more prolonged in the ice chest, than in the cellar; in the cellar than in the laboratory. It is also found that the temperature of the ice chest was lower than that of the cellar, and that of the cellar lower than that of the laboratory. It appears clear therefore that the "temperature after delivery" had an important influence upon the period during which the samples of milk remained sweet.

Influence of the combination of "Temperature on Delivery" and "Temperature after Delivery" upon the duration of sweetness.

The influence of the combination of these two temperatures may be most readily studied by considering the series of samples kept in the cellar and the series kept in the laboratory.

Those samples which arrived at temperatures varying from 61° to 70° F. and were subsequently stored in the cellar at temperatures which varied between 44° F. and 66° F. with an average minimum of 57·7° F. and an average maximum of 59·5° F. remained sweet for an average period of 3·35 days; those which arrived at temperatures between 51° F. and 60° F. and were then subjected to temperatures which varied between 43° F. and 61° F. with an average minimum of 49·2° F. and an average maximum of 51·4° F. remained sweet for an average period of 5·8 days; and those which arrived at temperatures varying between 41° F. and 50° F. and were then subjected to temperatures which varied between 35° F. and 49° F. with an average minimum of 42·4° F. and an average maximum of 44·1° F. remained sweet for an average period of 9·28 days. Those samples which arrived at temperatures between 61° F. and 70° F. and were subsequently kept in the laboratory at temperatures which varied between 53° F. and 76° F. with an average minimum of 59·8° F. and an average maximum of 67·6° F. remained sweet for an average period of 2·28 days; those which arrived at temperatures between 51° F. and 60° F. and were then subjected to temperatures which varied between 41·5° F. and 72·5° F. with an average minimum of 51·8° F. and an average maximum of 62·6° F. remained sweet for an average period of 3·9 days; and those which arrived at temperatures varying between 41° F. and 50° F. and were then subjected to temperatures which varied between 35° F. and 73·5° F. with an average minimum of 44·7° F. and an average maximum of 56·9° F. remained sweet for an average period of 4·95 days.

The period of sweetness of these samples was therefore in direct relation to the "temperature on delivery" and the "temperature after delivery."

The same fact is also clearly brought out by the curves shown in Chart II in which the samples have been arranged according to the temperatures at which they arrived at the laboratory between May, 1917, and February, 1918, and the numbers of days during which they remained sweet in the ice chest, the cellar and the laboratory are indicated.

A comparison of the three curves obtained for the samples which were kept in the ice chest, the cellar and the laboratory shows that those samples which were kept at the lowest temperature, that is to say, in the ice chest, remained sweet the longest; those which were kept at a higher temperature, that is to say, in the cellar, remained sweet for shorter periods; and those which were kept in the laboratory at the highest temperature remained sweet for the shortest periods.

It is quite clear that the temperatures at which the milk was kept after its arrival at the laboratory had an appreciable effect upon its keeping qualities. The responsibility of the consumer is thus made evident and the influence of temperature and time upon the keeping qualities of milk demonstrated.

The work further shows:

First, that during the period under review May 31st, 1917, to May 30th, 1918, no sample remained sweet for a period of less than 1·75 days. This period may have been longer since the samples were only examined once in each 24 hours.

Second, that of the 51 samples which were kept in the laboratory 40 were sweet at the end of 2·75 days and eleven were sweet for a period which was never less than 1·75 days, but was not as much as 2·75 days. It is interesting to note that of those samples which were sweet for the shortest periods, seven were received in the months of June, July and August, one at the beginning of September, 1917, and three during May, 1918.

Third, that of the 51 samples which were kept in the cellar 47 were sweet for a period which was never less than 2·75 days, and four were sweet at the end of 1·75 days but were sour at the end of 2·75 days.

Fourth, that with the exception of the one sample which has been discussed already, no sample which was kept in the ice chest remained sweet for a period of less than 7·75 days.

These experiments make it clear that well taken milk preserves its sweetness even under adverse conditions for considerable periods of time. They also show that the duration of those periods depends to a great extent upon the "temperature on delivery" and the "temperature after delivery."

It may be said that samples of this milk have been coming to the laboratory week by week for a period of 24 months and on no occasion has one arrived either tainted or sour.

Periods of sweetness of Average Milk when stored at different Temperatures.

The experiments concerning the keeping qualities of the samples of average milk were carried out in a manner exactly similar to that which has been described already for the samples of clean milk, but it should be noted that whereas the clean milk was from 22 to 26 hours old on arrival at the laboratory, the average milk was only about three hours old.

If the figures contained in Appendix II, an epitome of which is found in Table V, be examined, it is seen that 40 uncooled samples were stored in the ice chest, 41 in the cellar and a similar number in the laboratory.

Table V. *Average Milk. May*, 1917–*May*, 1918.

Uncooled milk Days sweet	Storage		
	Ice chest	Cellar	Laboratory
19	1	—	—
18	—	—	—
17	—	—	—
16	—	—	—
15	—	—	—
14	1	—	—
13	3	—	—
12	—	—	—
11	3	—	—
10	4	—	—
9	1	—	—
8	11	—	—
7	6	—	—
6	6	2	—
5	1	—	1
4	3	9	2
3	—	11	5
2	—	3	11
1	—	12	9
0	—	4	13
Total	40	41	41

Table V demonstrates clearly the great influence which these different methods of storage had upon the keeping qualities of the milk, for whereas in the ice chest the longest period of sweetness of any sample was 19 days, the shortest 4 days, and the great majority (36 out of 40 samples) remained sweet for 6 days or more, in the cellar no sample remained sweet for more than 6 days, and four samples, almost one-tenth of the total number, were already sour at the end of one day. Again, the longest period during which a sample remained sweet in the laboratory was 5 days, and thirteen samples, nearly one-third of the total number, were already sour at the end of 24 hours.

It is clear that the temperature at which the samples of milk were stored had a profound influence upon the periods during which they remained sweet.

Seasonal Variations in the keeping qualities of Average Milk.

A study of the figures in Table VI shows that of fifteen samples which were kept in the laboratory between the 31st of May and the 28th of September, 1917, eleven were sour at the end of 24 hours and four were sweet at the end of 24 hours, but sour at the end of two days. Of those which were kept in the cellar, four were sour at the end of 24 hours, ten remained sweet for 24 hours but had gone sour at the end of two days, and one was sweet at the end of two days, but did not last a third day.

Table VI. *Average Milk. Period of Sweetness.*

Period	No. of days sweet	Lab. No. of samples	Cellar No. of samples
31–5–17— 28–9–17	Less than one day	11	4
	1	4	10
	2	—	1
		Total 15	15
11–10–17— 15–11–17	Less than one day	—	—
	1	1	—
	2	3	—
	3	2	5
	4	—	1
		Total 6	6
17–1–18— 25–4–18	Less than one day	—	—
	1	1	—
	2	8	—
	3	3	5
	4	2	8
	5	1	—
	6	—	2
		Total 15	15
2–5–18— 30–5–18	Less than one day	2	—
	1	3	2
	2	—	2
	3	—	1
		Total 5	5
	Grand	Total 41	41

When the figures for the months of October and November, 1917, and January to April, 1918, are examined, it is found that no sample remained sweet for less than 24 hours, and of those which were kept in the laboratory only two for a period of less than two days. Of the samples which were kept in the cellar ten were sweet at the end of three days and the remainder all lasted for longer periods up to a maximum of six days.

The keeping qualities of the samples which were taken during the month of May, 1918, show a reversion to the conditions found during the period May to September, 1917. If the results of the examinations of the samples collected during these two periods be added together it is found that 20 samples were taken and were stored in the cellar and in the laboratory. Of those which were kept in the laboratory 13 were sour within 24 hours, 7 though sweet at the end of 24 hours, failed to last two days and none lasted longer than two days. On the other hand, of 21 samples which were stored in the laboratory during the periods October to November, 1917, and January to April, 1918, none were sour at the end of 24 hours, two were sweet at the end of one day but sour at the end of the second day and 19 were sweet for periods of two days or more. A comparison of the figures for the cellar gives similar results; thus of the 20 samples which were collected during the months May to September, four were sour at the end of one day, and twelve though sweet at the end of one day, did not last a second day, whereas no sample which was stored in the cellar during the periods October to November, 1917, and January to April, 1918, remained sweet for a period of less than three days.

It appears that there was a seasonal variation in the keeping qualities of these samples which were very unsatisfactory during the period from the 31st of May to the 28th of September, showed a distinct improvement during the period from the 11th of October to the 15th of November, and continued to improve during the period from January 17th to April 25th, 1918, after which their keeping qualities once more fell away to the conditions found at the same period during the previous year.

The figures contained in Table VI are confirmed by an examination of Chart III which shows the keeping qualities not only of the uncooled samples which were examined but also of those samples which were cooled between the 15th of November 1917 and the 10th of January, 1918. These samples are marked with the letter C in the Chart.

The curves for the samples which were kept in the cellar and in the laboratory show that the keeping qualities of this milk were least satisfactory during the period from the 31st of May to the 28th of September, 1917. There was an improvement during the month of October and the first half of November which was continued throughout the period from the 17th of January to the 25th of April, 1918. During the month of May, 1918, the curve fell once more to the level found during the period May to September, 1917.

The curve for the ice chest shows a curious alternation; thus the milk was always sweet for at least six days during the period from the 31st of

May to the 28th of June; during July, August and September the keeping qualities of the milk were even better than they were in the earlier months, but during the periods from the 18th of October to the 15th of November, there was a very distinct fall until the lowest point in the curve (four days) was reached. This fall may have been a pure accident, but it is an interesting fact that a similar decline at this season of the year was found in the clean milk samples. The curve showing the period of sweetness of the samples which were taken between the 17th of January and the 4th of April, 1918, is again upward, and is on the whole at a higher level than that which was found for those samples which were taken during May and June, 1917, but from the 4th of April to the 30th of May, 1918, there is a steady fall in the curve until it finally reaches the same level that was found at the same period of the previous year.

Effect of Temperature upon the keeping qualities of these Samples.

The facts which have been set forth demonstrate first that the temperature of storage had a great influence upon the keeping qualities of the milk, and second, that these qualities varied at different seasons of the year, being more satisfactory during the colder months than they were during the warmer months. It may be of interest, therefore, to study in more detail the effect of the temperatures on delivery and the temperatures after delivery upon the keeping qualities of the samples. With this object in view Table VII has been prepared. It shows the temperatures at which the samples arrived, the average periods during which they remained sweet, the minimum and maximum temperatures to which they were subjected during these periods and the averages of these. An examination of the temperature records contained in the table reveals the fact that on the whole the temperatures at which the milk was arriving and the temperatures at which it was subsequently kept were varying in the same direction in the cellar and in the laboratory. This is most clearly demonstrated by the cellar temperature, but is shown also by the laboratory temperatures, though in the latter case the temperature records are influenced by the use of fires, etc. If the samples which were kept in the cellar and in the laboratory be considered it is found that of 21 samples which arrived at temperatures between 80° F. and 85° F. and were subsequently stored in the cellar at temperatures which varied between 42° F. and 64·5° F. with an average minimum of 56·4° F. and an average maximum of 59·6° F. four did not remain sweet for 24 hours and the average duration of the period of sweetness of the remaining 17 was 1·5 days, while of 12 samples which arrived at temperatures between 75° F. and 79° F. and were then subjected to temperatures which varied between 39° F. and 58·5° F., with an average minimum of 45·2° F. and an average maximum of 49·3° F. no sample remained sweet for a period of less than one day, and

Table VII. *Average Milk. Influence of Temperature.*

Temp. on arrival ° F.	No. of samples	ICE CHEST					CELLAR					LABORATORY				
		Av. No. days	Av. min.	Av. max.	Min.	Max.	Av. No. days	Av. min.	Av. max.	Min.	Max.	Av. No. days	Av. min.	Av. max.	Min.	Max.
80–85	21	8	33	36·8	32	40	1·5* (17 samples)	56·4	59·6	42	64·5	1·25† (8 samples)	60	68·39	44	76
75–79	12	9·4	32·9	35·7	32·5	37	3·58	45·25	49·3	39	58·5	2·58	46·7	61·25	35	69
66–74	8	7·7 (7 samples)	33	35·5	33	36	3·62	42·6	47·3	40·5	51	2·25	46·1	63·4	42	72·5
C 46–53	8	8·37	32·5	35·7	31	38	3·75	42·6	45·3	38	53·5	2·37	57·3	65·6	34	73·5

* 4 samples already sour at the end of 24 hours.

† 13 samples already sour at the end of 24 hours.

the average duration of sweetness was 3·58 days. Again, eight samples reached the laboratory at temperatures which varied between 66° F. and 74° F. These were stored in the cellar at temperatures which varied between 40·5° F. and 51° F. with an average minimum of 42·6° F. and an average maximum of 47·3° F., none of these samples remained sweet for a period of less than three days and the average period of sweetness was 3·6 days. These results make it clear that the keeping qualities of these samples of milk did depend to a very large extent upon the temperatures at which they arrived at the laboratory and upon the temperatures at which they were subsequently kept. If they be compared with those found in the laboratory where the temperature conditions were higher than in the cellar, and with those samples which were kept in the ice chest where the milk was effectively chilled, the importance of the temperature factor is still further brought out. Thus, of 21 samples which arrived at temperatures between 80° F. and 85° F. and were subsequently kept in the laboratory at temperatures which varied between 44° F. and 76° F. with an average minimum of 60° F. and an average maximum of 68·3° F. 13 were already sour at the end of 24 hours, and of the remaining eight only one remained sweet for more than one day. The average duration of sweetness of these eight samples was 1·25 days. Again, the 12 samples which arrived at temperatures which varied between 75° F. and 79° F. and were then stored in the laboratory at temperatures which varied between 35° F. and 69° F. with an average minimum of 46·7° F. and an average maximum of 61·2° F. remained sweet for an average period of 2·5 days, and none remained sweet for less than one day. The eight samples which arrived at temperatures between 66° F. and 74° F. and were subsequently stored in the laboratory at temperatures which varied between 42° F. and 72·5° F. with an average minimum of 46·1° F. and an average maximum of 63·4° F. remained sweet for an average period of 2·25 days, and none of these samples remained sweet for less than two days.

If now we turn to a consideration of the samples which were stored in the ice chest, it is found that the efficient chilling to which they were subjected had a very marked effect upon the periods during which they remained sweet. It may be well to note that the temperatures at which they were kept were remarkably steady, varying between 32° F. and 38° F. since there is no record of a temperature of 39° F. throughout the experiments, and 40° F. was only recorded upon one occasion. The effect of these temperatures upon the periods of sweetness of the samples is shown in Table VII from which it appears that the 21 samples which arrived at temperatures varying between 80° F. and 85° F. remained sweet for an average period of eight days, the 12 samples which arrived at temperatures varying between 75° F. and 79° F. remained sweet for an average period of 9·4 days, and the eight samples which arrived at temperatures varying between 66° F. and 74° F. of which only seven were put in the ice chest, for an average period of 7·7 days. The shortest period during which any sample remained sweet in the ice chest was four days. Three such samples were found. They all occurred in the months of October and November and each one belongs to a different division of the three groups into which the temperatures have been divided. It appears from these experiments that when these samples of average uncooled milk were sufficiently chilled, within three hours of milking, they were kept sweet for a minimum period of four days, and that the period of sweetness of the milk which was not chilled, depended to a great extent upon the temperatures at which it arrived, and upon the temperatures at which it was kept after arrival. Thus, milk which reached the laboratory at temperatures between 80° F. and 85° F. could not be kept sweet with certainty for one day at temperatures which varied between 42° F. and 64° F. with an average minimum of 56° F. and an average maximum of 59° F. On the other hand milk which reached the laboratory at temperatures which varied between 75° F. and 79° F. and was subsequently kept at temperatures which varied between 39° F. and 58° F. with an average minimum of 45° F. and an average maximum of 49° F. remained sweet for an average period of 3·5 days with a minimum of one day, and that which reached the laboratory at temperatures between 66° F. and 74° F. and was subsequently kept at temperatures which varied between 40° F. and 51° F. with an average minimum of 42° F. and an average maximum of 47° F. remained sweet for an average period of 3·6 days with a minimum of three days.

The results of the bacteriological examinations of the samples of

Clean and Average Milk.

Method of Examination.

1. *General Count* (*a*) *Dilutions employed.*

Between the 28th of November, 1916, and the 31st of May, 1917, the milk was plated out in dilutions of $\frac{1}{100}$ c.c., $\frac{1}{1000}$ c.c., $\frac{1}{10,000}$ c.c., and $\frac{1}{100,000}$ c.c. It was sometimes found that no colonies grew in the $\frac{1}{100}$ c.c. dilution and that not infrequently the number of colonies was very small. From the 7th of June, 1917, onwards the plates made from the clean milk samples have therefore been prepared from the following dilutions: $\frac{1}{10}$ c.c., $\frac{1}{100}$ c.c., $\frac{1}{1000}$ c.c., $\frac{1}{10,000}$ c.c.

(*b*) *Media employed.*

Between the 28th of November, 1916, and the 1st of November, 1917, the samples of milk were plated upon + 10 whey gelatine; after that date upon neutral whey agar.

In all cases the plates were incubated at 22° C. and counted at the end of 48 hours and five days.

2. *Search for lactose fermenting organisms.*

The milk in quantities of 1 c.c., $\frac{1}{10}$ c.c., $\frac{1}{100}$ c.c., $\frac{1}{1000}$ c.c., $\frac{1}{10,000}$ c.c. was inoculated into lactose-peptone water tubes containing Durham's tubes. The inoculated tubes were then incubated at 37° C. and at the end of 48 hours and of five days were examined for the presence or absence of gas formation.

Clean Milk.

Between November 28th, 1916, and May 30th, 1918, 77 samples of clean milk were examined, three of these were already more than 40 hours old when they arrived in the laboratory and are therefore excluded from this account. One sample which arrived on the 11th of October, 1917, contained an organism which liquefied gelatine so that no accurate count could be made; no gas was found in the corresponding lactose-peptone water tubes which were inoculated from this sample. There remain 73 samples from which complete results were obtained. 70 of these samples were from 22 to 26 hours old at the time of the examination, and three which arrived during November and December, 1916, were from 18 to 19 hours old. Chart IV demonstrates that on only two occasions was a bacterial count of more than 10,000 obtained from any sample. On one of these occasions a count of 200,000 was found but 1 c.c. of the sample failed to produce acid and gas in lactose-peptone water. On the other occasion the number of colonies from $\frac{1}{10,000}$ c.c. could not be counted, and $\frac{1}{100}$ c.c. showed the presence of organisms capable of producing acid and gas in lactose-peptone water.

Chart VI demonstrates that organisms which were capable of producing acid and gas in lactose-peptone water were found upon eight occasions, and that the smallest quantity in which such organisms were obtained was $\frac{1}{100}$ c.c. These results are still further brought out by Table IX which demonstrates clearly how clean this milk was when measured by a bacteriological standard, since 70 of the 73 samples examined gave a count of 6000 or less, and 58 a count of 1500 or less. On three occasions no colonies were found on the plates which had been prepared from this milk, with the result that whereas in the early days the lowest dilution from which plates were made was $\frac{1}{100}$ c.c. it is now $\frac{1}{10}$ c.c., and even so a sample occasionally arrives in which no colonies are found.

Average Milk.

The bacteriological examinations of the samples of average milk which came into the laboratory between November 23rd, 1916, and May 30th, 1918, were made in the same manner as those of the clean milk, save that it has been found necessary to make the counts from plates made from dilutions of the samples varying between $\frac{1}{100}$ c.c. and $\frac{1}{100,000}$ c.c. For commercial reasons the milk from this farm was cooled to the temperature of town tap water during parts of the months of November, December and January. Fifteen such samples were examined in the course of the investigations and this fact is indicated in the charts by the letter C. Although it is probable that the cooling to which it was subjected had an influence upon the subsequent keeping qualities of the milk, it did not bring it within the definition of clean milk, that is to say, milk which does not contain more than ten thousand colonies in 1 c.c. when it is delivered to the consumer, and it was not able to prevent the demonstration of the presence of organisms which were capable of producing acid and gas in lactose-peptone water. It has not been thought necessary, therefore, to exclude these samples from the description of the bacteriological results which were obtained in the course of this work.

Sixty-nine samples were examined. Their ages varied from a minimum of four hours to a maximum of 12¾ hours, but only one sample had attained this age. The remainder were all examined at ages which varied between 4 and 12 hours, eleven being from 10 to 12 hours old, forty-four from 8 to 10 hours old, and thirteen from 4 to 8 hours old. During the period from July 5th, 1917, to May 30th, 1918, all the samples save three (Aug. 16th and Oct. 5th, 1917, and Feb. 21st, 1918) were between eight and 9¾ hours old at the time of their examination. It is clear that all the average milk samples were examined at an age which was much less than that of the clean milk.

Table VIII demonstrates that 24 samples gave a bacterial count of 10,000 or less, and that the number of colonies found in 45 samples was more than 10,000. Of these 27 did not contain more than 200,000 colonies in 1 c.c. Table VIII also brings out the fact that the presence of organisms capable of producing acid and gas in lactose-peptone water increased with the increase in the bacterial count of the samples. Thus of the 24 samples of which the count was ten thousand or less, twelve showed acid and gas formation, of the 27 samples of which the count lay between ten thousand and two hundred thousand, twenty showed acid and gas formation, of the six samples

Table VIII.

No. of colonies in 1 c.c.	No. of samples in which found	Presence or absence of acid and gas in lactose-peptone water from 1 c.c. or less of sample	
		Present	*Absent*
More than 10,000,000	6	6	—
1,000,000—10,000,000	6	6	—
200,000—1,000,000	6	5	1
10,000—200,000	27	20	7
0–10,000	24	12	12

the count of which lay between two hundred thousand and a million five showed acid and gas formation, and the samples of which the counts were above a million always showed the presence of these organisms.

Comparison of the Bacteriological Results obtained from the Samples of Clean and Average Milk.

Charts V and VI give a comparison of the bacterial counts and of the occasions upon which lactose fermenting organisms were found in the samples of clean and average milk. Chart V shows that although the age of the average milk at the time of examination was from 4 to 12 hours and that of the clean milk from 22 to 26 hours, yet the bacterial count of the clean milk maintains an almost uniform level, while that of the average milk varies greatly from week to week so that on one occasion it may be below 10,000, on another 14,000,000 or more. It further shows that even when the average milk was cooled, the bacterial count was still irregular and high. Chart VI demonstrates that organisms capable of producing acid and gas in lactose-peptone water were present in the clean milk upon eight occasions, and the lowest dilution in which they were ever found was $\frac{1}{100}$ c.c. In the average milk, on the other hand, they were found upon forty-nine occasions, and the lowest dilution in which they were demonstrated was $\frac{1}{10,000}$ c.c. Here again it is clear that the cooling of the milk did not prevent the appearance of these organisms, for 15 samples were cooled and 13 of them contained lactose fermenting organisms sometimes in dilutions as high as $\frac{1}{10,000}$ c.c.

Table IX brings out these results in a somewhat different form. It shows that whereas 71 of the clean milk samples gave a bacterial count of 10,000 or less, only 24 such counts were found among the average milk samples, and if an examination of the lower end of the table be made it is seen that whereas no less than 70 of the 73 samples of clean milk gave a count of 6000 or less, only 13 such samples were found in the average milk. It is a very interesting fact that 62 of the clean milk samples gave a count of 2000 or less in spite of the long journey and the influence of the varying temperatures to which they had been exposed before reaching the laboratory. The figures showing the presence of lactose fermenting organisms which are given in the same table demonstrate once more the great difference that existed between these two types of milk, for whereas they were found upon eight occasions in the clean milk, their presence was demonstrated upon forty-nine occasions in the average milk, and this in spite of the fact that the age of the average milk was many hours less than that of the clean milk.

Table IX.

No. of colonies in 1 c.c.	No. of samples		Lactose fermenting (acid and gas) organisms present	
	Clean milk highest dilution 1/10,000 c.c.	Average milk highest dilution 1/100,000 c.c.	Clean milk	Average milk
Above 200,000	1	18	1	17
10,000–200,000	1	27	—	20
9500–10,000	1	2	1	1
9000–9500	—	1	—	1
8500–9000	—	1	—	—
8000–8500	—	1	—	1
7500–8000	—	—	—	—
7000–7500	—	1	—	—
6500–7000	—	2	—	2
6000–6500	—	3	—	—
5500–6000	3	—	1	—
5000–5500	—	—	—	—
4500–5000	—	1	—	—
4000–4500	1	1	—	1
3500–4000	1	1	—	1
3000–3500	2	3	—	1
2500–3000	—	1	—	1
2000–2500	1	1	—	—
1500–2000	4	1	1	—
1000–1500	6	3	—	3
500–1000	14	1	2	—
0–500	38	—	2	—
Total	73	69	8	49

References.

(1) *The Milk Supply—A Suggestion.*

(2) "Wastage of Milk," *J. of R.A.S.E.*

(3) *Second Interim Report of the Committee on Milk Production and Distribution.*

APPENDIX I.

BACTERIOLOGICAL EXAMINATIONS OF CLEAN COOLED (Max. 62° F. / Min. 45° F.) BOTTLED MILK.

Experiments carried out over a period of 18 months.

November 1916 to *May* 1918.

DATE	Age of sample in hours	Temperature of cooling ° F.	Temperature on arrival ° F.	Number of colonies in 1 c.c.	Acid and gas in 1 c.c. or less
1916					c.c.
Nov. 28	19½	—	—	1,200	—
Nov. 30	22½	—	—	1,500	+ 1
Dec. 7	19½	—	—	1,100	—
Dec. 15	18½	—	—	1,900	—
Dec. 28	24	—	—	900	—
1917					
Jan. 4	24	—	—	1,600	—
Jan. 11	22½	—	—	300	+ 1
Jan. 18	23	—	—	300	—
Jan. 25	22½	—	—	Nil	+ 1/10
Feb. 1	22¾	—	—	1,000	—
Feb. 8	22½	—	—	400	—
Feb. 15	23	—	—	400	—
Feb. 22	22	—	—	3,900	—
Mar. 1	22½	—	—	200	—
Mar. 8	23	—	—	160	—
Mar. 15	23	—	—	340	—
Mar. 22	23	—	—	270	—
Mar. 29	23¼	—	—	400	—
April 5	22½	—	—	500	—
April 12	24	—	—	400	—
April 19	25	—	—	Nil	—
April 26	25	—	—	370	—
May 10	25½	—	—	300	—
May 17	25	—	53	700	—
May 24	26	—	65	700	—
May 31	25	—	68	5,500	+ 1
June 7	23¼	—	71	1,640	—
June 14	24½	—	76	200,000	—
June 21	23	—	64	5,600	—
July 5	22½	—	60	460	—
July 12	24¼	—	67	360	—
July 19	22½	—	66	230	—
July 26	22½	—	71	1,400	—
Aug. 2	24	—	62	310	—
Aug. 9	24	—	62	280	—
Aug. 16	26½	59·5	65	10,000	+ 1/100
Aug. 23	22½	62	69	1,020	—

DATE	Age of sample in hours	Temperature of cooling ° F.	Temperature on arrival ° F.	Number of colonies in 1 c.c.	Acid and gas in 1 c.c. or less
1917					c.c.
Aug. 30	22½	56	61	900	+ 1
Sept. 6	22½	62	68	5,900	—
Sept. 27	23	56	61	540	—
Oct. 4	22¾	56	60	370	—
Oct. 11	22½	56	52	Liquefact'n	—
Oct. 18	23¼	56	54	∞ in 1/10,000	+ 1/100
Oct. 25	22¾	52	54	570	—
Nov. 1	22½	55	58	2,300	—
Nov. 15	23	52	51	3,000	—
Nov. 22	22¾	52	57	3,100	—
Nov. 29	22½	51	62	500	—
Dec. 6	22½	50	43	400	—
Dec. 13	22½	50	50	150	—
Dec. 20	22½	46	37	170	—
Dec. 27	22½	—	49	240	—
1918					
Jan. 3	22½	46	50	4,000	—
Jan. 10	22	51	49	1,200	—
Jan. 17	22½	45	44	400	—
Jan. 24	23	50	56	300	—
Jan. 31	22½	—	45	350	—
Feb. 7	23	50	55	800	—
Feb. 14	22½	50	48	800	—
Feb. 21	22	—	46	200	—
Feb. 28	22	48	49	460	—
Mar. 7	22½	49	46	600	—
Mar. 14	23	50	51	600	—
Mar. 21	22½	51	52	110	—
Mar. 28	22½	50	50	250	—
April 4	22½	50	51	40	—
April 11	22½	54	50	10	—
April 18	21½	50	44	Nil	—
April 25	22¼	51	55	500	—
May 2	22¼	52	50	400	—
May 9	22¼	55	56	240	—
May 16	22	54	63	300	—
May 23	22¼	62	60	500	+ 1
May 30	22¼	57	66	300	—

NOTE.—Acid and gas indicate the presence of lactose-fermenting organisms.
∞ = uncountable.

APPENDIX II.

BACTERIOLOGICAL EXAMINATIONS OF AVERAGE UNCOOLED MILK.

Experiments carried out over a period of 18 months.

November 1916 to *May* 1918.

Date	Age of sample in hours	Temperature on arrival ° F.	Number of colonies in 1 c.c.	Acid and gas in 1 c.c. or less
1916				c.c.
Nov. 23	6½(*c*)	—	33,000	—
Nov. 30	8 (*c*)	—	17,100	+1
Dec. 7	8¼ (*c*)	—	14,000	+1/10
Dec. 14	4¼ (*c*)	—	90,000	—
Dec. 22	10 (*c*)	—	97,000	+1
1917				
Jan. 5	10 (*c*)	—	420,000	+1/10
Jan. 11	4 (*c*)	—	31,000	+1
Jan. 18	6½	—	34,000	—
Jan. 25	5¾	—	8,500	—
Feb. 1	9¼	—	11,200	—
Feb. 8	8½	—	9,300	+1
Feb. 22	4½	—	14,200	+1/10
Mar. 1	4½	—	16,200	+1/10
Mar. 8	4½	—	86,000	+1/10
Mar. 15	8½	—	6,000	—
Mar. 22	8½	—	1,300	+1
Mar. 29	6½	—	4,400	+1/10
April 5	4¼	—	38,000	+1/10
April 12	10	—	4,700	—
April 19	11	—	12,200	+1/10
April 26	10	—	6,600	+1
May 3	10½	—	230,000	+1
May 10	11	—	1,200,000	+1/1000
May 17	11	53	6,100	—
May 24	12¾	65	14,700,000	+1/1000
May 31	11½	69	Uncountable	+1/10,000
June 7	9½	71·6	17,900,000	+1/1000
June 14	11	76	Uncountable	+1/10,000
June 28	11½	67	Uncountable	+1/10,000
July 5	9	63	1,300,000	+1/100
July 19	8	66	2,000,000	+1/100
July 26	8½	70	2,500,000	+1/10,000
Aug. 2	9	63	960,000	+1/10
Aug. 16	6¾	64	91,000	+1
Sept. 6	9	68	Uncountable	+1/100
1917				c.c.
Oct. 5	4	56	53,000	+1
Oct. 18	9¾	59	45,000	—
Oct. 25	9¼	60	6,000	—
Nov. 1	9	68	320,000	—
Nov. 8	8¾	55	3,000	—
Nov. 15	9½	61	3,800	+1/100
Nov. 22	9½ (*c*)	62	70,000	+1/100
Nov. 29	9¼ (*c*)	62	6,800	+1/10,000
Dec. 6	9¼ (*c*)	55	30,000	+1/10,000
Dec. 13	9¼ (*c*)	58	69,000	+1/100
Dec. 20	9 (*c*)	46	53,000	+1/10
Dec. 28	9 (*c*)	48	120,000	+1
1918				
Jan. 3	8 (*c*)	50	1,200	+1/100
Jan. 10	8 (*c*)	52	440,000	+1/10
Jan. 17	9¼	56	10,000	—
Jan. 24	8½	58	8,000	+1/1000
Jan. 31	9¼	56	14,000	—
Feb. 7	9½	60	10,000	+1/10
Feb. 14	9¼	54	7,000	—
Feb. 21	4	59	1,700	—
Feb. 28	8	64	3,400	—
Mar. 7	9½	54	90,000	+1/100
Mar. 14	9½	58	2,700	+1
Mar. 21	9	57	3,200	+1
Mar. 28	8½	55	1,200	+1/100
April 4	8½	58	800	—
April 11	9	51	2,300	—
April 18	8½	48	20,000	—
April 25	9	57	96,000	+1/100
May 2	9	54	40,000	+1/1000
May 9	9¼	62	2,000,000	+1/100
May 16	9	64	200,000	+1/1000
May 23	9¼	64	2,000,000	+1/1000
May 30	9	62	500,000	+1/100

NOTE.—Acid and gas indicate the presence of lactose-fermenting organisms.
(*c*) indicates that the sample was cooled.

CHARTS I—VI

CHART I

SEASONAL CURVES

For Clean Cooled (45°—62° F.) Milk (22—26 hrs. old) Stored at Different Temperatures

The figures on the curves represent the temperatures on arrival

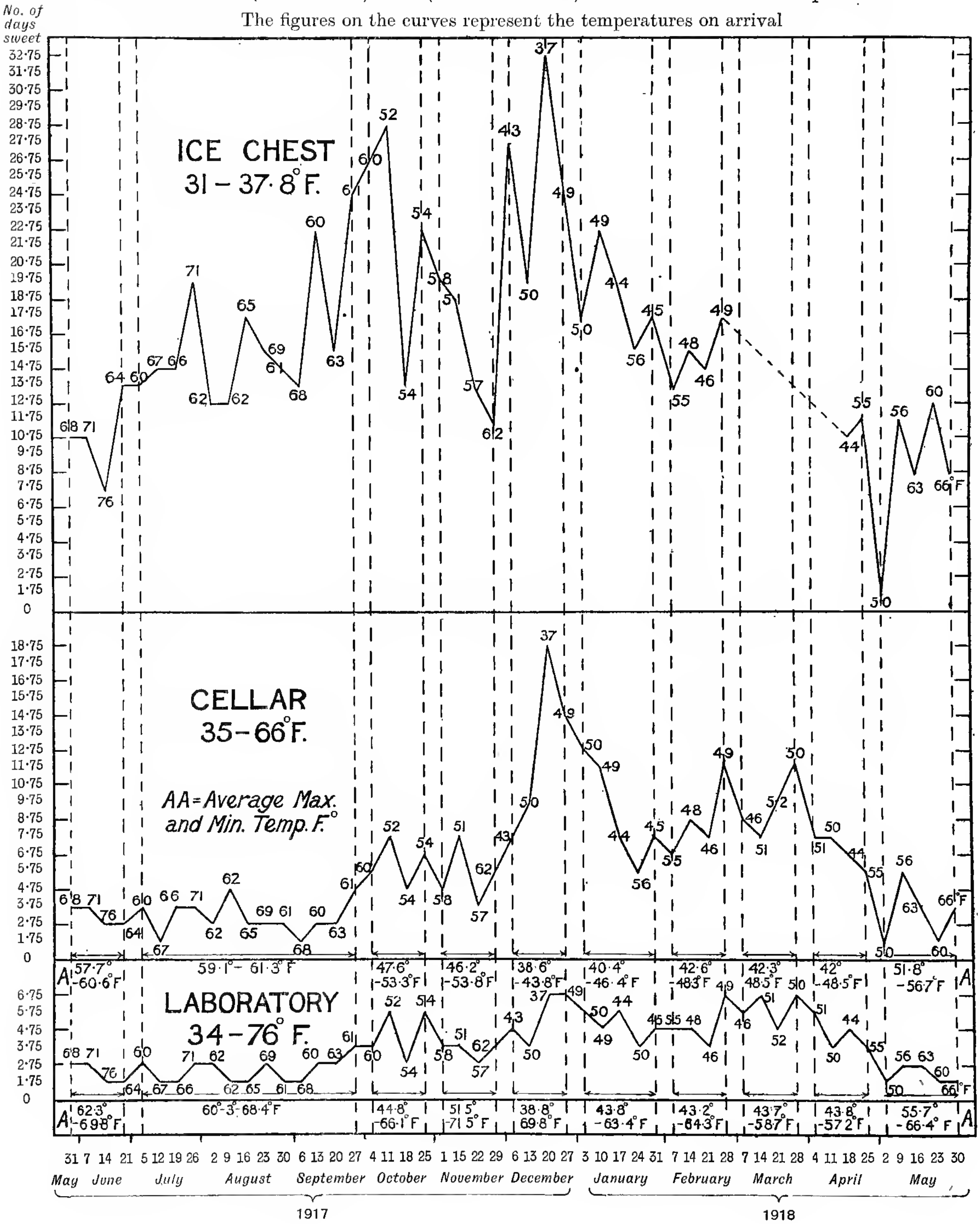
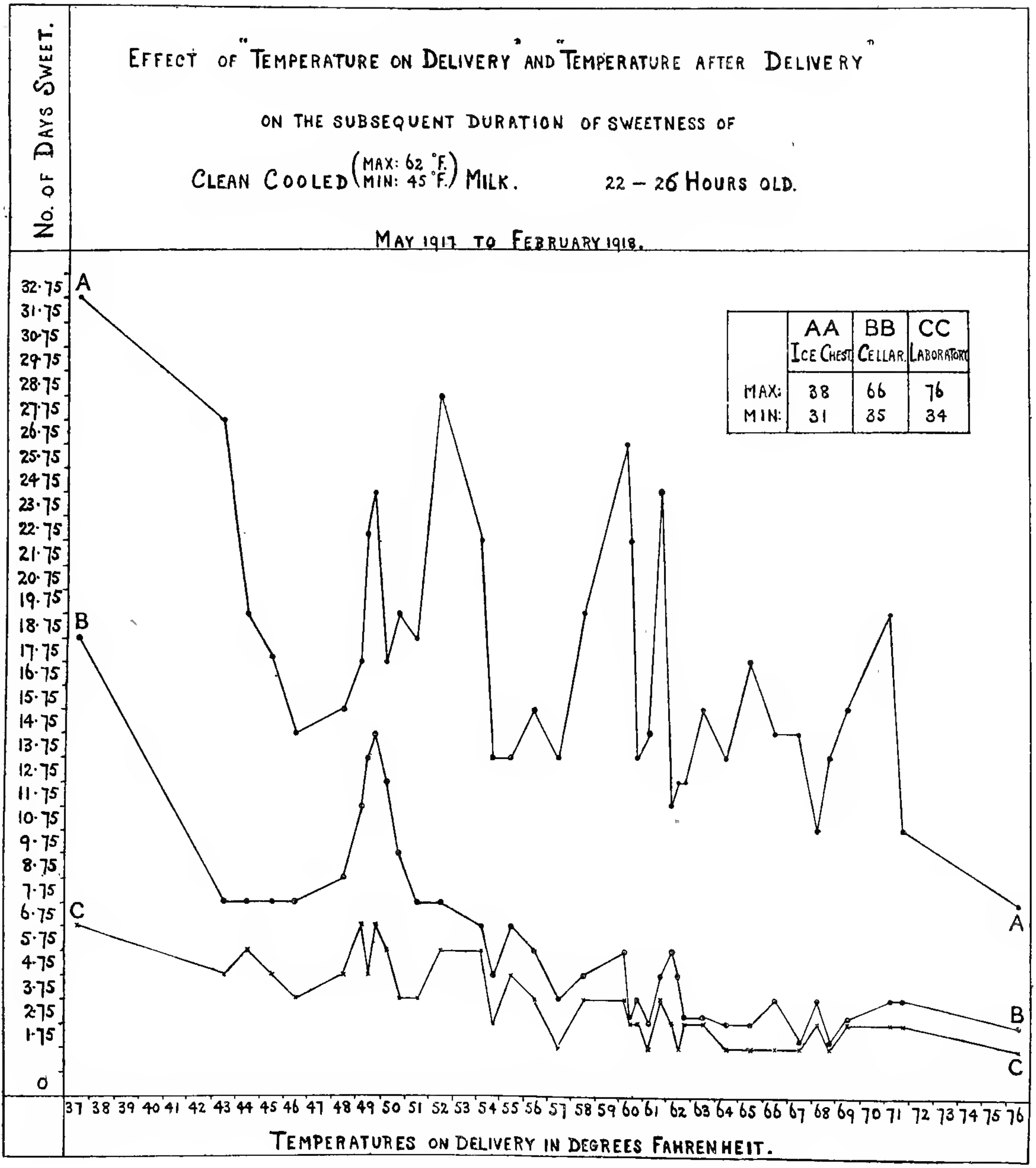


CHART II


No. of Days Sweet.
Effect of "Temperature on Delivery" and "Temperature after Delivery"
on the subsequent duration of sweetness of
Clean Cooled (Max: 62 °F. Min: 45 °F.) Milk. 22 – 26 Hours old.
May 1917 to February 1918.
AA Ice Chest
BB Cellar
CC Laboratory
Max: 38 66 76
Min: 31 35 34
32·75
31·75
30·75
29·75
28·75
27·75
26·75
25·75
24·75
23·75
22·75
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2·75
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0
A
B
C
A
B
C
37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56 57 58 59 60 61 62 63 64 65 66 67 68 69 70 71 72 73 74 75 76
Temperatures on Delivery in Degrees Fahrenheit.

CHART III

SEASONAL CURVES

for AVERAGE UNCOOLED MILK. 3-4 HOURS AFTER MILKING STORED AT DIFFERENT TEMPERATURES

'C' INDICATES SAMPLE WAS COOLED.

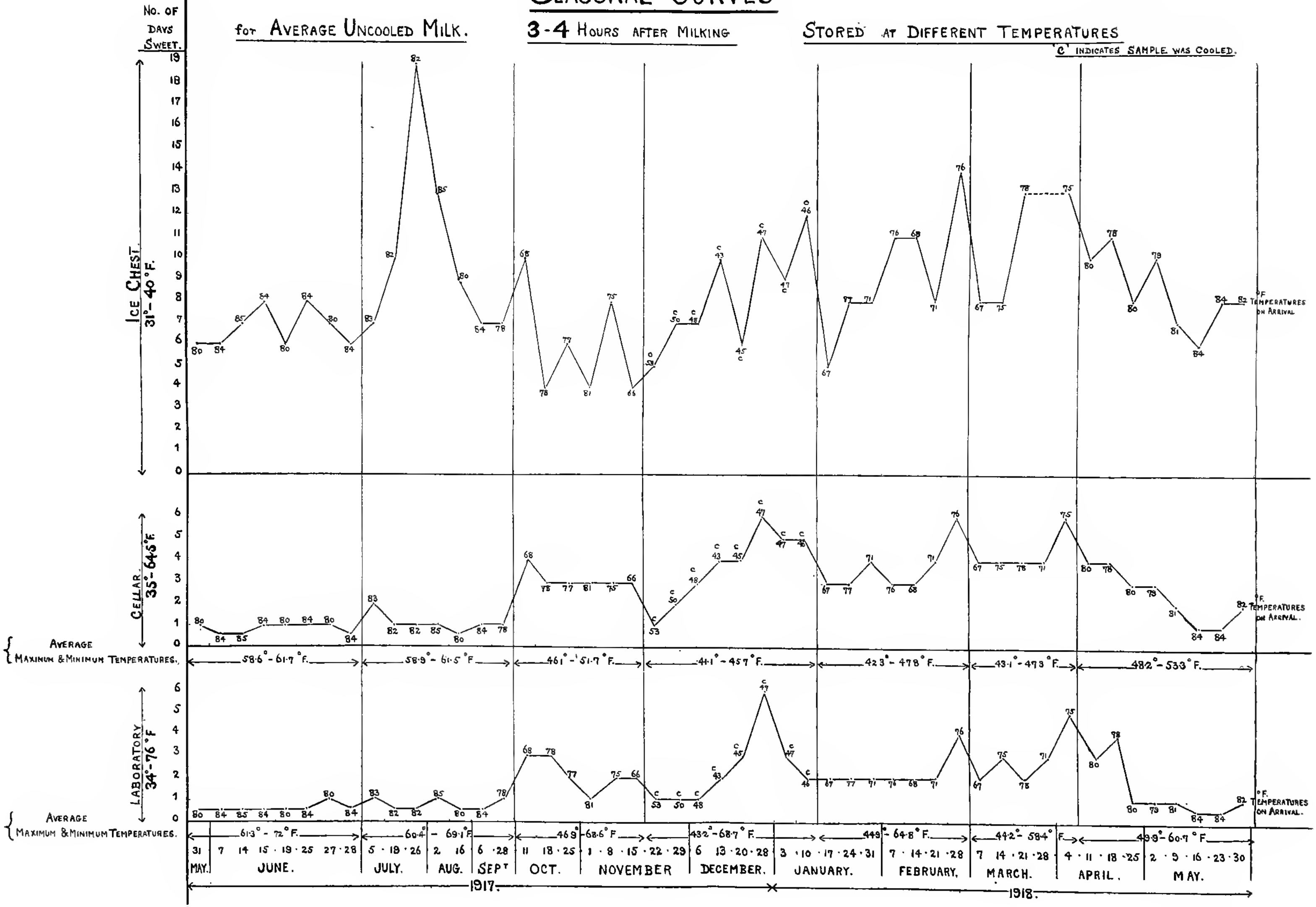


CHART IV

BACTERIOLOGICAL EXAMINATIONS

Of Clean Cooled Milk (45°—62° F.) 22—26 hours old.
November 28th 1916 to May 30th 1918

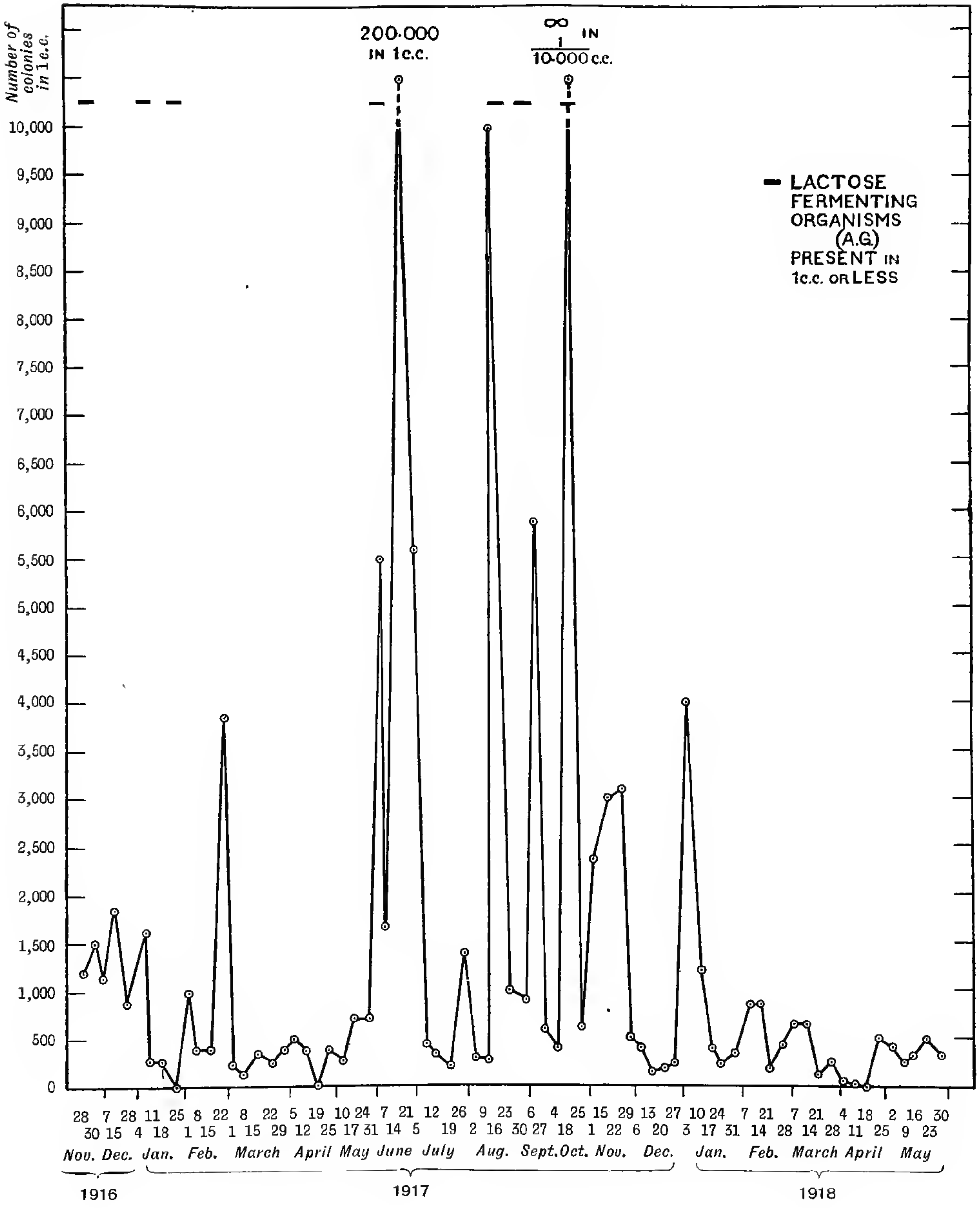


CHART V

BACTERIOLOGICAL EXAMINATIONS

Of Clean Cooled Milk (45°—62° F.) 22—26 hours old and
Average Uncooled Milk 4—12 hours old

C indicates that sample was cooled

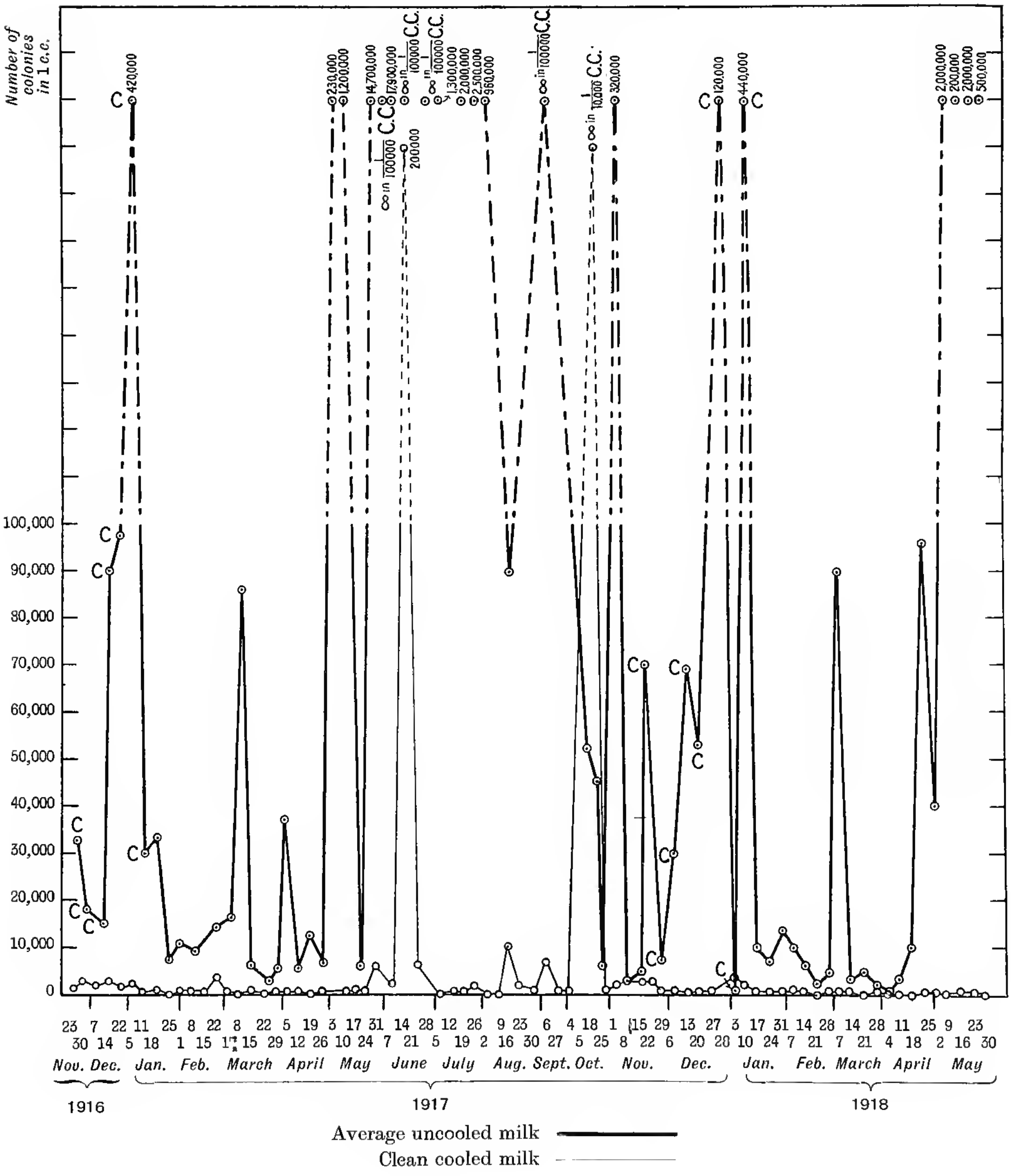
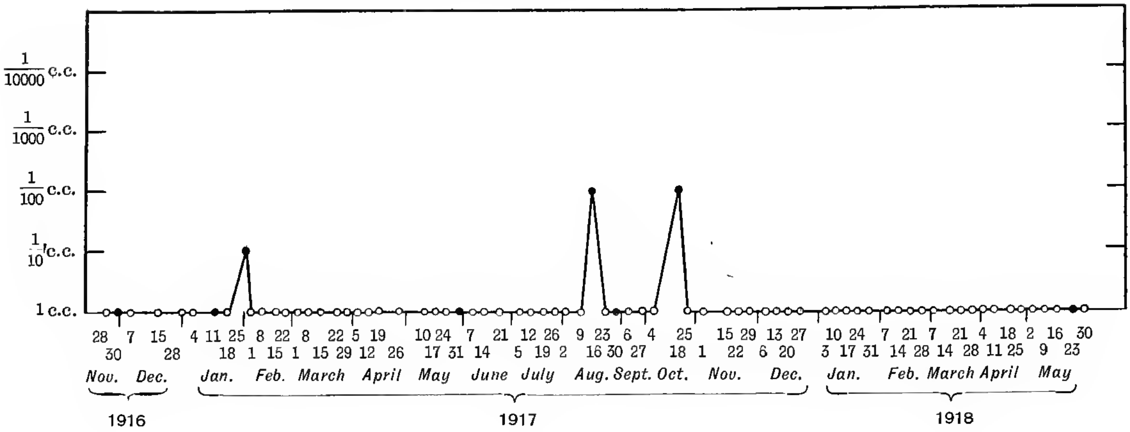


CHART VI

PRESENCE OR ABSENCE OF LACTOSE FERMENTING ORGANISMS

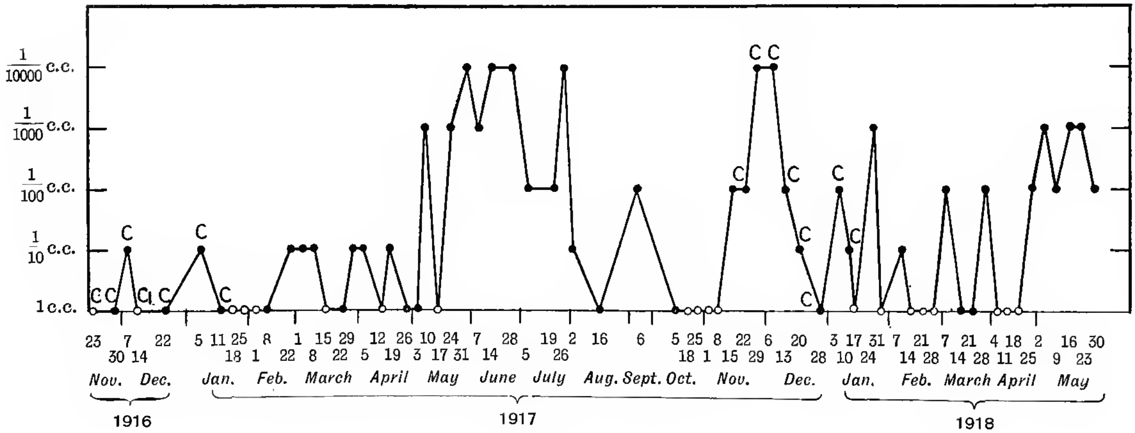
● Present in 1 c.c. or less. ○ Absent

Clean Cooled Milk (45°—62° F.) 22—26 hours old



Average Uncooled Milk (4—12 hours old)

C indicates that sample was cooled



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